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ADAPTATIONS AMONG INSECTS OF FIELD AND FOREST

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IT is well known that there are more kinds or species of insects in the world than of all other animals. The number has been placed by various authorities at from one to ten million and careful estimates indicate that we have in the State of New York some 20,000 kinds or species of insects, all differing from each other by more or less striking characters and in the great majority of species, there are also recognizable variations between the eggs, the maggots, larvae or caterpillars, and the pupae or chrysalids, not to mention striking differences between the life habits of these varied forms.

Summarizing, we have among insects an immense complex exhibiting innumerable variations, some large, many minor and practically all significant. It is proposed to examine briefly some of the more striking of these differences in the hopes of reaching a better understanding of the insect problem as a whole.

It happens that some years ago a list of all the insects known to occur in the State of New Jersey was prepared and a careful analysis of this shows that nearly one-half of all the insects therein recorded are plant feeders, about one-sixth are predaceous, living mostly upon other insects, another one-sixth are scavengers and live mostly upon decaying organic matter and one-eighth are parasitic upon other animals, mostly insects.

Among plant feeders we find one or more species living at the expense of practically every growing plant. It may be that some plants, such as oak and apple trees, are particularly adapted to insect requirements and support a very large number of species. It may also be observed that practically all parts of the plant are liable to attack, including the roots, the wood or bark of the trunk, of the larger limbs, of the smaller limbs, the buds, the developing leaves and flowers in the buds, the fully developed flowers, the expanded leaves, the immature fruit and the mature fruit; and broadly speaking there are insects which confine themselves exclusively or nearly so to the parts designated. This restriction is so marked that we have a large series of small beetles known as seed weevils, because they live almost entirely in seeds of various plants. There is one entire family, the members of which

bore almost exclusively in the bark and outer sap wood of trees and because of this habit they are commonly known as bark beetles. Many of the plant feeders, it might be added, are considered injurious because of the extensive losses they cause in cultivated crops; but it should be remembered that comparatively few of the many plant feeders are numerous enough to be of economic importance.

The predaceous insects, approximately one-sixth of all the species, habitually prey upon smaller animals, mostly insects, and are indirectly beneficial because they destroy intentionally or otherwise many destructive forms. The rapid, active, brightly colored tiger beetles, many of the ground beetles, the ferocious dragon flies, the peculiar aphid lions (the young of the lazy golden-eyed fly), all come in this category together with many others.

The scavenger insects, comprising the burying beetles, many flies, etc., are nearly as numerous as the predatory forms and, like other insects, exhibit marked variations in structure and habits.

The parasites, somewhat less numerous than the two preceding groups, are in many cases indirectly beneficial since they prey upon injurious forms and incidentally hunt their prey under conditions which would frequently seem to promise immunity from attack. Here we find hyperparasitism which may involve three or even four of these pirates working in the same host and each attacking the one ahead, as it were.

Semi-aquatic and even aquatic insects are not protected by the surrounding water from parasites and also borers inhabiting deep galleries in hard wood by no means escape many enemies of this character. Even the caterpillars of the pitch moth, living and moving about readily in pitch and covered with this medium for a large proportion of their existence succumb to the attacks of these vigilant enemies. There is one entire family of small parasites which specialize upon insect eggs, some being so minute that they can develop successfully in the extremely small codling moth egg, which latter has a diameter only about one-half that of the head of an ordinary pin and is furthermore very flat and scale-like.

A general survey of insects as a whole shows all manner of variations from the minute midge approximately one-fiftieth of an inch in length to our largest moths or grass-hoppers with a wing spread of some eight inches. There are endless modifications in form from the oval body of certain beetles or even scale insects to the extremely attenuated forms such as dragon flies and walking sticks. The principal organs of the body, such as the antennae or feelers, the eyes, the legs and the wings are modified in innumerable ways and in some insects have disappeared entirely while in others they have been developed to an extraordinary degree.

We have been taught that insects have heads, wings, and legs and pass through four stages of development, namely, the egg, the larva or the caterpillar, the pupa or chrysalis and the adult; and yet modification has proceeded to such an extent that it is possible to find some insects where both structures and stages have been eliminated or concealed to such an extent that, in a broad sense, there are species or stages with and without such important accessories as heads, wings, legs, mates, eggs, larvae, pupae or chrysalids and adults.

There is also a very great variation in the time required to pass through the various transformations or what is known as the life-cycle, this ranging from approximately 7 days in certain species of plant lice or aphids to 17 years in the case of the periodical cicada, sometimes known, though improperly, as the 17 year locust.

Insects and warm weather are synonymous so to speak and yet snow fleas may be found by the millions on snow in late winter, canker worm moths fly and deposit eggs under equally adverse conditions and at this season a peculiar wingless crane fly as well as the odd *Boreus* may be found crawling upon the snow. The Arctic regions fairly swarm with mosquitoes which have adapted themselves to the rigors of existence in the far north and issue in clouds in the cool, Arctic spring; nevertheless it is true that most insects abound during warm weather and the midsummer months of the temperate zone and the tropical regions are remarkable for their abundance. Some thrive best under humid conditions and others have adapted themselves to the arid wastes of desert regions. These are simply suggestions regarding climatic diversities endurable by insects.

Turning from the general to special instances, aphids or plant lice illustrate in a striking manner the possibilities of relatively defenseless forms maintaining themselves under adverse conditions. These are all soft bodied insects with indifferent powers of flight and slow movement on foot; nevertheless there are something over 300 species living upon a considerable variety of plants and frequently occurring in enormous numbers. Individually, they are not particularly prolific, they are preyed upon by a considerable series of aggressive parasites and predators; but in spite of these handicaps are able to maintain themselves, because many of them produce a generation within a very short time, some 7 days, and in addition certain species at least periodically migrate to other plants. One migration is from birch to witchhazel and vice versa. This change enables the aphids to escape, for a time at least, from the frequently abundant natural enemies on the infested trees and it also provides the insects with fresh and more acceptable food, since badly infested plants soon become unsuitable for the maintenance of the insects.

The indirect effect of climate is well illustrated among aphids since a rise in temperature in warm weather in the spring is favorable to the development of a number of efficient enemies and consequently such conditions are very likely to result in a speedy control of a plant louse outbreak through natural agencies.

Certain gall making aphids exhibit very striking adaptations. Some species only curl the leaves and through such distortion obtain considerable protection from the elements and presumably also from parasites, while certain of these forms simply establish themselves upon the part of the plant selected and apparently, as a result of the withdrawal of sap due to its feeding, the adjacent plant cells grow up around the insect and eventually inclose it with protective walls, within which the mother plant louse and her young develop in security. There is such a close adaptation between plant and insect in some cases that the aphid is dependent upon finding a given species of plant and being able to establish itself upon a certain developing part, such as a leaf stem, the base of the leaf or the developing shoot.

Biological modifications among plant lice have gone farther than this and we not only find an alternation of food plants with a more or less well defined migration but also, in some species, well marked alternations of series of generations, these series being so different that before the connection was established, they were supposed to belong to entirely different species.

There is a very intimate relation between many insects and the host plant and this is especially close in the case of the oaks and the long series of gall wasps, a large and peculiar group, mostly confined to the oaks, remarkable because of the varied forms of the numerous galls they produce and noteworthy on account of the fact that a considerable series presents a peculiar phenomenon known as alternation of generations. This may be briefly described as a series of unlike alternate generations; in other words parents and children are unlike, while parents and grandchildren are alike. It appears to be a special adaptation due to the fact that one generation frequently develops upon the leaves while the other lives in galls on the twigs or even roots. The adults of one appear in warm, midsummer weather and those of the other issue under the inclement conditions of late fall or early spring.

The long series of plant feeding insects mentioned above show marked specialization in the case of some forms which actually live upon a peculiar fungus cared for and grown by themselves. This may easily be seen in the case of a number of our timber beetles, insects which make deep galleries in the dying wood of trees and utilize the moist conditions there present for the growing of a small fungus known as *Ambrosia*, which they carry from one tree to another. Certain species of ants, mostly tropical or sub-tropical, cultivate fungi in under-

ground chambers to which they carry portions of leaves cut from trees, using this material as a stratum upon which to grow the fungus.

It should be noted in addition that insects may be found in almost every environment. There are the salt marsh mosquitoes, for example, represented by several species, each with distinct limitations and yet so well adapted to the struggle for existence that one species, at least, may be found breeding in saline pools hundreds of miles from salt marshes. The series of fresh water mosquitoes is larger, exhibits even wider and more varied adaptations than the salt marsh forms and as an extreme case we may mention the peculiar mosquito which lives only, so far as known, in the water of pitcher plants. The silted bottom of shallow pools affords a suitable habitat for small midge larvae, one species of which may be utilized to render milk waste from creameries and cheese factories inoffensive. The maggots of another small fly are important agents in rendering sewage innocuous. The quieter portions of fresh water streams are inhabited by many caddis worms with their peculiar cases, the rapids in such streams support large patches of black fly larvae and between the adjacent stones, there may be found the delicate silken webs of fishing caddis worms. Some aquatic forms have developed to such an extent that they thrive by the millions in the very saline or alkaline lakes of the west and in at least one case the maggots of a small fly develop in pools of petroleum, a product frequently used for the destruction of insect life.

The same varied life conditions obtain among terrestrial forms. Insects are found in almost every conceivable situation, though abundance is dependent to a very great extent upon environment. One of the most remarkable cases of adaptation is found in the buffalo carpet beetle and its close allies. One species has been able to maintain itself for 17 years in an ear of very dry popcorn kept in a practically hermetically sealed fruit jar. More remarkable than this, an investigator has recently demonstrated that grubs of these beetles react to conditions so perfectly that the normal process of molting to permit increase in size and development to maturity may be reversed and in the prolonged absence of suitable nourishment these grubs may actually molt and decrease in size; and not only this but the process may be continued in either direction in individual cases through a series of molts by simply providing or withholding suitable nourishment. This behavior may well be considered an extreme illustration of adaptability so commonly found among insects.

A general knowledge of insects suggests that they have developed in such varied forms and abundance because of an inherent adaptability which has enabled them to exist under a great variety of conditions. This adaptability to environment has been sealed as it were by persistent tendencies toward structural variations, which latter incline to

become more defined whenever a group is somewhat isolated, a condition very likely to follow variations in habit. It is difficult otherwise to explain the almost endless structural modifications found among insects, because it would severely tax human ingenuity to defend them all on the ground of their bestowing a distinct advantage upon the possessor, except possibly, as suggested above, in more firmly establishing specific distinctions and the usual accompanying variations in habits. The relatively long series of similar species of such well segregated units as the cut worms and grass web worms in the Lepidoptera and the June beetles in the Coleoptera, indicate very material advantages in biological adaptations, subsequently confirmed by minor structural variations, since deviations from the normal mean a wider field for the unit as a whole and consequently a greater probability of the type persisting.

Consideration of the general problem compels the admission that insects have gained their present important position in the natural world through an adaptability unequalled in other groups. This has been accomplished by variations favorable to the invasion of unoccupied territory rather than by forcing other organisms into the background, aside from the inevitable limitations, in many cases important, which insects have imposed upon plant life. It is noteworthy that this status should be occupied by a group of comparatively weak, defenseless creatures and the fact that this has been done indicates the possibilities of adaptation. Insects have succeeded where apparently better endowed forms failed, largely because of their greater adaptability.